RADC-TR-81-44
In-House Report
March 1981

VHF INTRUDER DETECTION TECHNIQUE: TESTS WITH A C-5A AIRCRAFT

Livio D. Poles
K.V.N. Rao
Nicholas V. Karas
John Antonucci

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

This report has been reviewed by the RADC Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be releasable to the general public, including foreign nations.

RADC-TR-81-44 has been reviewed and is approved for publication.

APPROVED:

PHILLIP BLACKSMITH, Chief
EM Techniques Branch
Electromagnetic Sciences Division

APPROVED:

ALLAN C. SCHELL, Chief
Electromagnetic Sciences Division

FOR THE COMMANDER: John P. Huss

JOHN P. HUSS
Acting Chief, Plans Office

If your address has changed or if you wish to be removed from the RADC mailing list, or if the addressee is no longer employed by your organization, please notify RADC (EEC), Hanscom AFB MA 01731. This will assist us in maintaining a current mailing list.

Do not return this copy. Retain or destroy.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RADC-TR-81-44	2. GOVT ACCESSION NO. AD-A203 944	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) VHF INTRUDER DETECTION TECHNIQUE: TESTS WITH A C-5A AIRCRAFT		5. TYPE OF REPORT & PERIOD COVERED Scientific. Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Livio D. Poles, K.V.N. Rao, Nicholas V. Karas, John Antonucci		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Deputy for Electronic Technology (RADC/EEC) Hanscom AFB Massachusetts 01731		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62702F 46001501
11. CONTROLLING OFFICE NAME AND ADDRESS Deputy for Electronic Technology (RADC/EEC) Hanscom AFB Massachusetts 01731		12. REPORT DATE March 1981
		13. NUMBER OF PAGES 19
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Leaky coaxial cable
Zone of detection
Susceptibility to interference

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the results of the evaluation of an RF intruder detection technique developed to protect individual resources. Tests were conducted at Dover AFB, Delaware, in conjunction with parked C-5A aircraft and were designed to determine some specific characteristics of performance. The system consisted of a leaky coaxial cable, surrounding the aircraft, that acted as a distributed antenna; monopole receiver antennas located within the cable perimeter; and appropriate electronic signal equipment to generate, receive and process the signals. The results show the extent of the zone of

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(14) (6) (9) (10) (16) (17) 25 (11) (12) 21 Rept. 309050 A

Cont'd

Block 20 (continued)

detection and the susceptibility of the system to interference from aircraft taxiing nearby. Optimum location of monopole antennas under a single C-5A aircraft to minimize shadowing effects was also determined.

Contents

Illustrations

VHF Intruder Detection Technique: Tests with a C-5A Aircraft

1. INTRODUCTION

A number of studies and experiments have been conducted[1-4] to investigate the properties of a new intruder detection technique called the Single Wire Individual Resource Protection Sensor (SWIRPS).

The technique was developed to provide a method of protecting parked aircraft or other high-value resources from intruders. A phenomenological

Received for publication 2 Mar 1981

1. Karas, N.V., Poirier, J.L., Antonucci, J.A., and Szczytko, M., Sgt, USAF (1978) A VHF Intrusion Detection Technique for Isolated Resources, RADC-TR-78-177.

2. Poirier, J.L., Karas, N.V., Antonucci, J.A., and Szczytko, M., Sgt, USAF (1977) VHF Intrusions Detection: A Technique for Parked Aircraft, RADC-TR-77-384.

3. Rochefort, J.S., Sukys, R., and Poirier, N.C. (1978) An Area Intrusion Detection and Alarm System, RADC-TR-78-258.

4. Karas, N.V., Antonucci, J.A., and Szczytko, M., Sgt, USAF (1978) A VHF Intruder Detection System: Tests on a C-5A Aircraft, RADC-TR-78-230.

theory[5-7] was developed to describe the performance of the system, and several measurements[4] were made to verify the validity of the basic sensor concepts. However, additional measurements were deemed necessary (a) to determine the sensitivity of the system to detect aircraft and maintenance vehicles moving near the protected aircraft, (b) to estimate the mutual interference of adjacent systems, and (c) to determine an optimum placement of the monopole receiving antennas under the aircraft to be protected. The report describes measurements performed during two days near a parked C-5A aircraft at Dover AFB, Delaware to evaluate these aspects of sensor operation.

The basic setup used in the measurements is shown in Figure 1. A low-power VHF transmitter excites a loop of leaky coaxial cable that encircles the

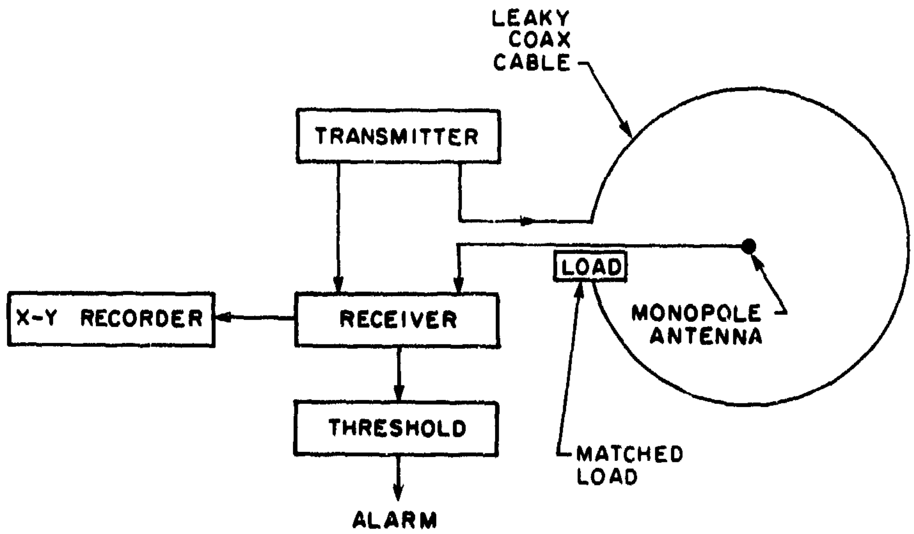

Figure 1. Experimental System Layout

5. Poirier, J.L., and Kushner, M. (1979) Analysis of the Response of an RF Intruder Protection System, RADC-TR-79-17.

6. Poirier, J.L. (1979) Effect of Multiple Receiving Antennas on the Response of an RF Intrusion Sensor, RADC-TR-79-42.

7. Poirier, J.L. (1980) Estimation of the Zone of Detection of the Single Wire Individual Resource Protection Sensor, RADC-TR-80-175.

aircraft, and a receiver is connected to one or more monopole antennas located within the loop. An intruder who enters the detection zone near the leaky cable sensor loop disturbs the ambient energy coupling between the cable and antenna. This disturbance produces a change in the level of the received signal that is processed and, if sufficiently large, a detection is declared to alert the security forces.

2. MEASUREMENTS

2.1 General Discussion

The experiment consisted of recording the changes in amplitude of the RF energy coupled from the leaky coax cable to the monopole antenna as an intruder penetrated the zone of detection. This zone is confined to the vicinity of the cable. For most of the tests reported here, the variation in coupling was recorded as a person walked around the aircraft, immediately adjacent to the cable. These test walks are called "circumferential walks."[1] Previous measurements[4] have indicated that the changes in the amplitude of the signal could be related to the sensitivity of the system to detect radial penetrations. The system response to a penetration along any radius, therefore, could be estimated from the circumferential walk results. The curve shown in Figure 2 was chosen to explain typical coupling variations measured during a circumferential walk along

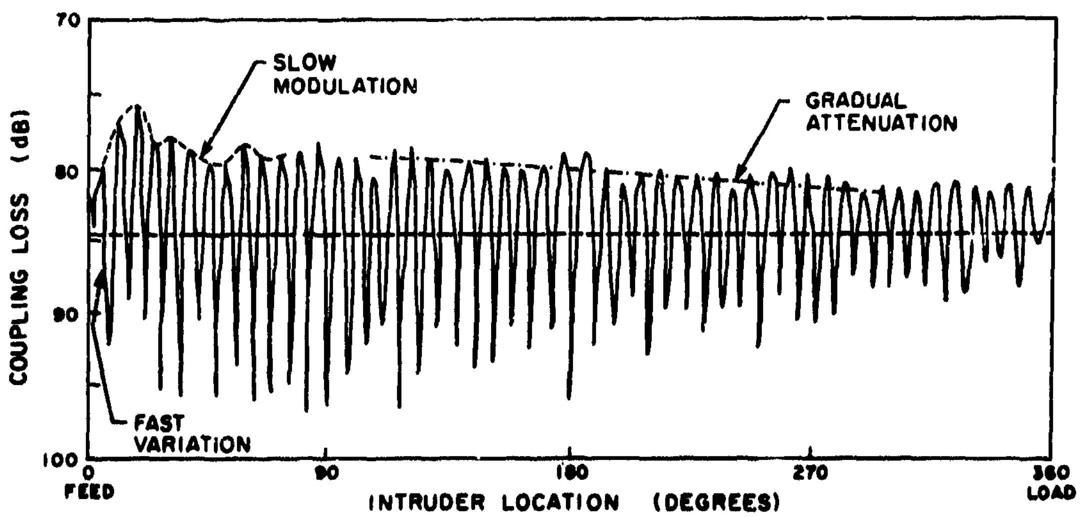

Figure 2. Variation in Received Power for a Circumferential Path (L = 152 m)

a loop of leaky coaxial cable with no enclosed resources. Two types of periodic variations can be seen: one is a fast variation in which the response changes rapidly above and below the reference level; the other is a slow modulation of the peaks. In addition, there is a gradual attenuation in the response from 0° to 360°. This is produced by the attenuation of the leaky coax cables which was about 2 dB/ 100 ft. The fast variation is the result of the interaction of the ambient field with the perturbing field produced by the intruder. The phase and amplitude of the scattered field change as the intruder moves along the cable. The variation depends on the operating frequency and the propagation velocity of the fields on the cable. The slower variations result from the interaction of the surface wave outside of the cable with the signal traveling inside the leaky coaxial cable. The period of this oscillation depends on the relative velocities of the signal traveling inside and of that traveling outside the cable.

The leaky coaxial cable (CERT 285, perimeter = 750 ft) which encircled C-5A shown in Figure 3 was lying on a concrete parking ramp, just beneath the nose,

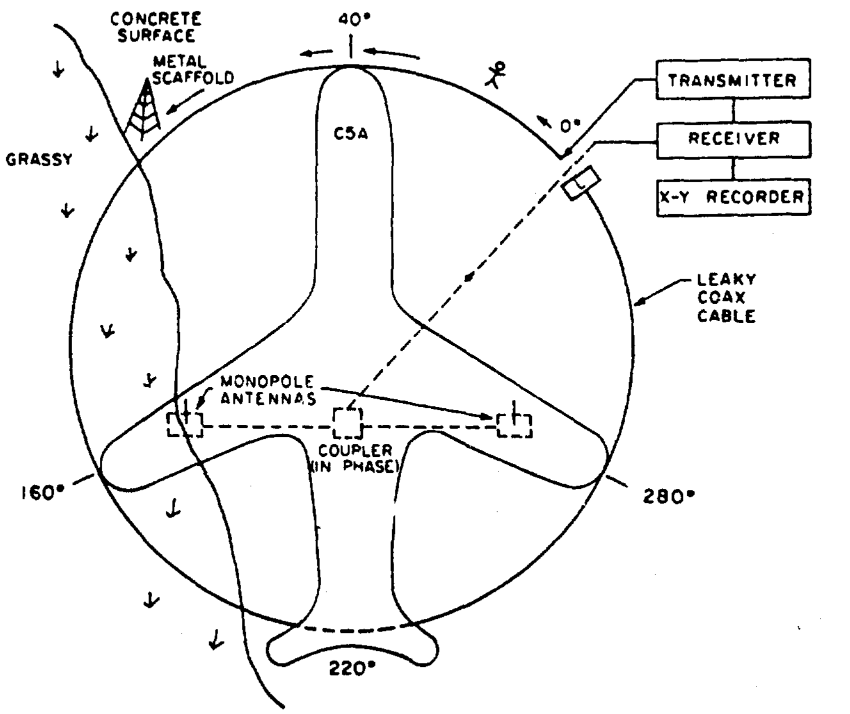

Figure 3. Field Site Layout (Circumferential Walk Tests)

the tail, and the wing tips of the C-5A. RF energy (80 MHz) was fed to one end of the cable; the other end was terminated in a matched load. The feed and load ends were positioned within a few feet of each other to form a closed loop. This junction marked the point from which the azimuth angle of the intruder was measured (counterclockwise). A network analyzer was used to generate the CW signal for the leaky cable, and to receive the RF energy from the monopole antenna. The RF signal power received from the antennas was recorded on the y-axis of a recorder whose x-axis was calibrated to indicate the azimuthal position of the intruder. The input power to the cable was 10 mW, although the power radiated by the inefficient leaky cable was considerably less. The leaky coaxial cable to monopole coupling loss ranged from 60 dB to 110 dB, with 85 dB being typical. The detector bandwidth was set at 10 kHz for all reported measurements.

2.2 Antenna Location

The 15 in. clearance between the fuselage and the parking ramp surface, when the C-5A is in the download position, does not allow the placement of an appropriate VHF antenna under the aircraft's body. Thus, the antenna must be placed to one side of the aircraft. This configuration shields the antenna from the intruder for about half of the perimeter. To detect an intruder over the entire perimeter, therefore, it was necessary to use two antennas; one on each side of the aircraft, as shown in Figure 3.

In the first series of tests, a single monopole was placed beneath the left wing, then beneath the right wing. Figures 4 and 5 show the SWIRPS response

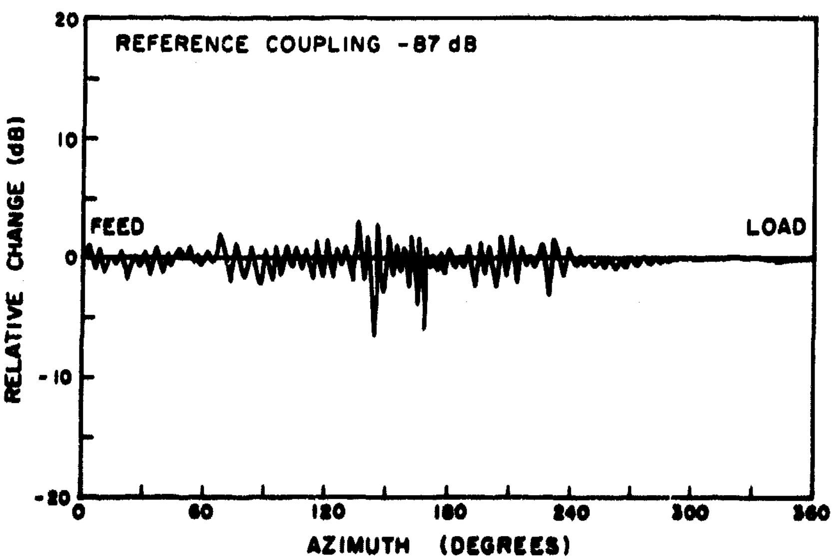

Figure 4. System Response With Single Monopole Under Left Wing

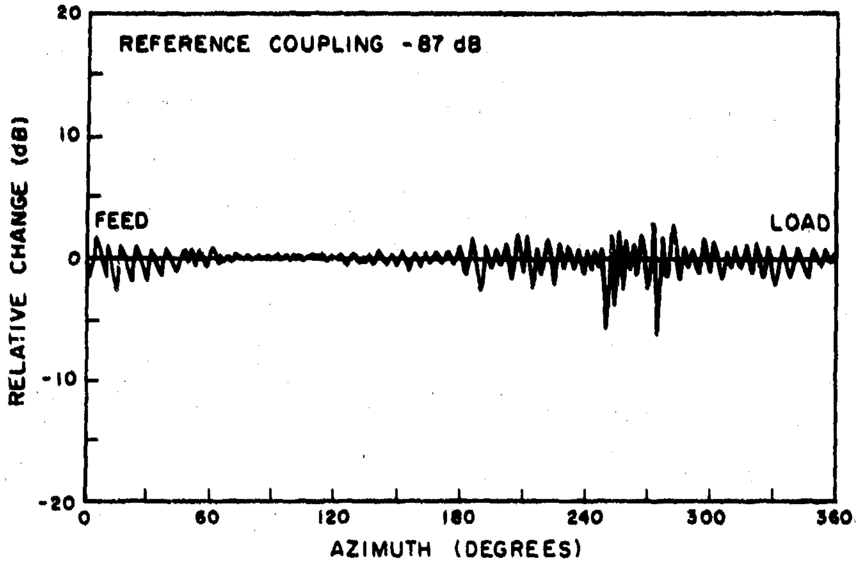

Figure 5. System Response With Single Monopole Under Right Wing

using a single monopole for a circumferential walk by a human intruder. Both the responses show considerable regions where the amplitude of the received signal power is low due to shielding from various aircraft parts. Reference to Figure 4 shows that the amplitude of the response remains below 1 dB between angles of about 240° to 40°, the region where the intruder is shielded from the monopole by the aircraft. This small response indicates that the probability of detecting an intruder in this sector is low. Decreasing the threshold would improve detection performance, but would also raise the false (nuisance) alarm rate by making the system too sensitive in other regions of the perimeter. Measurements taken with the antenna under the right wing, as shown in Figure 5, also display the effect of shielding. Here, the weak response occurs primarily from 50° to 170°.

The system response of two coupled monopoles under both wings instead of one monopole under either wing was investigated. Figure 6 shows that for this dual antenna configuration, the amplitude of the system response was above 1 dB for all azimuthal angles, and thus did not result in any extensive shielded zones as in the previous two figures.

To explore the effect of eleveted antennas, the two coupled antennas were raised 2-1/2 m from the ground without changing their location. Figure 7 shows a marked increase in the amplitude of the response at all azimuthal angles. This increase indicated that the threshold can be set high enough to make the system relatively insensitive to false alarms. The change in the reference coupling,

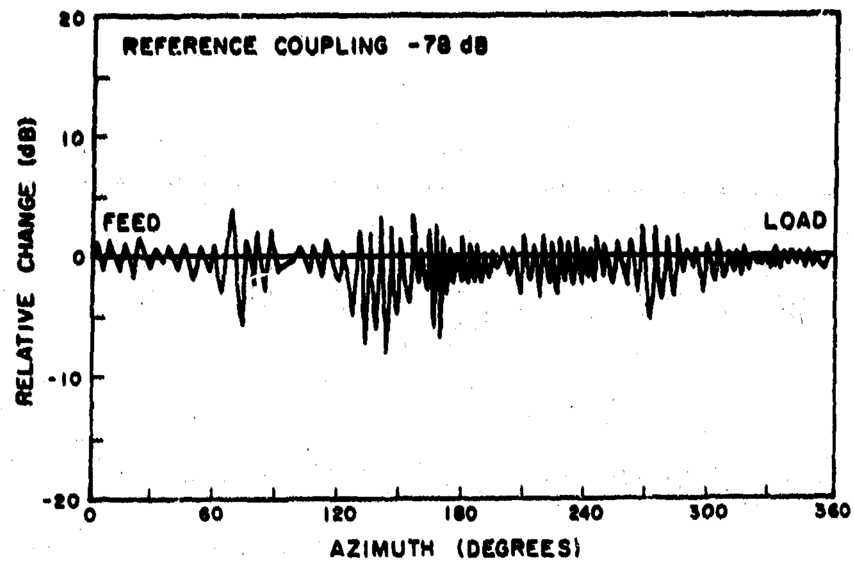

Figure 6. System Response With Two Monopoles Under Wings

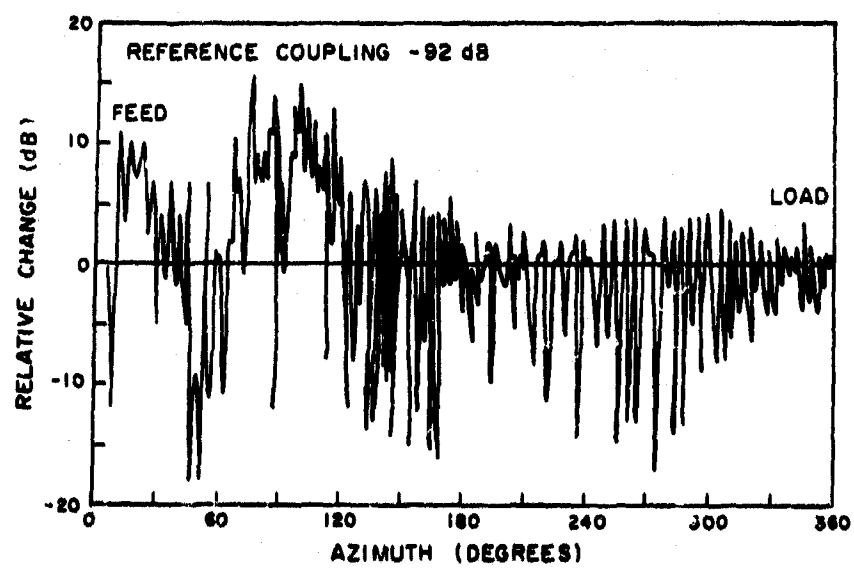

Figure 7. System Response With Two Raised Monopoles Under Wings

-92 dB in Figure 7, compared to -78 dB in Figure 6, may be due to interference of signals. Lower ambient signals, however, have the effect of increasing the relative response observed as an intruder enters the detection area of the system. A formal explanation of this behavior is described by Poirier,[7] where it is pointed out that the greatest response occurs when the power of the signal scattered by the intruder is equal to the power of the ambient signal. It was also demonstrated that as the signal power scattered by the intruder gets larger than the ambient signal, a shift in the average power level occurs. This behavior is evident in the sector from 60° to 120° of Figure 7.

2.3 Zone of Detection

It was necessary to determine the response of the SWIRPS to the various types of activities that normally occur in an operational environment. This knowledge will aid in designing a system for a particular zone of detection. The test layout is shown in Figure 8. Two coupled antennas, raised 2-1/2 m above the ground (one beneath each of the wings) were used as receivers.

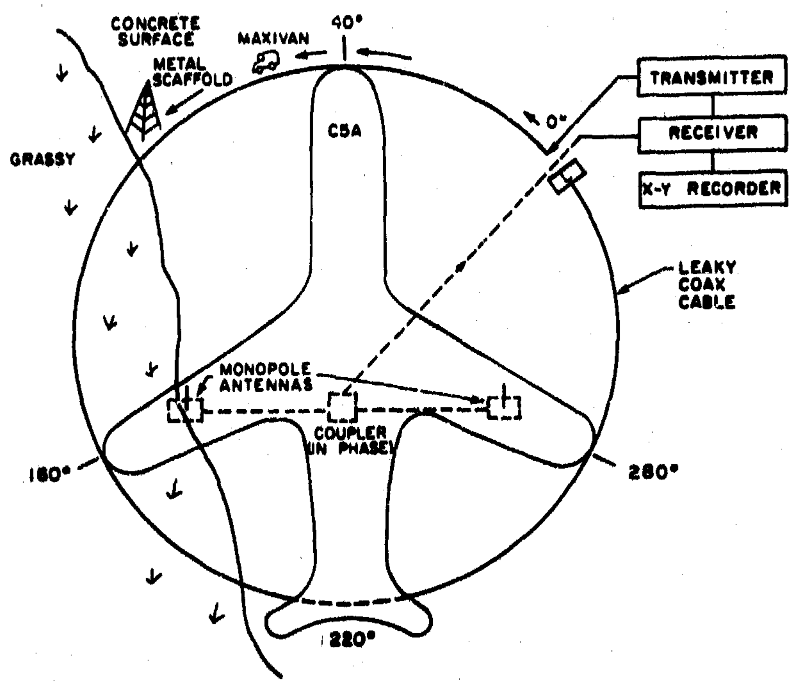

Figure 8. Field Site Layout (vehicle intrusion tests)

Figures 9, 10, and 11 show the system response to a maxivan driven around the perimeter at various distances from the sensor cable. Figure 9 shows that the vehicle causes large amplitude fluctuations when it is 0.5 m from the cable but that the amplitude response drops sharply as seen in Figures 10 and 11 as the separation between the cable and maxivan increases. At 3.5 m the response remains below 1 dB for the entire perimeter except for an increased response, as indicated in Figures 10 and 11, in the region near 90° that is the result of a distortion of the path followed by the van required by the presence of an obstructing scaffold. The van has to be driven towards the antenna for a 100 ft long segment thus making the response larger within that region.

To evaluate the effect on the systems response of aircraft taxiing near the SWIRPS some additional tests were made. A system was deployed around a C-5A aircraft (Figure 12) that was parked at right angles to the ramp leading to the runways. The leaky coax was fed so that its most sensitive portion (feed) was near the nose of the parked aircraft. Another C-5A, taxiing at its normal speed, passed by on the ramp. The distance of closest approach between the two aircraft was about 15 m and occurred when the wing tip of the moving aircraft was opposite the nose of the parked aircraft. The taxiing aircraft caused a negligible change in the ambient signal of the deployed system. It should be mentioned that during these tests no interference from aircraft avionics operating in the area was observed.

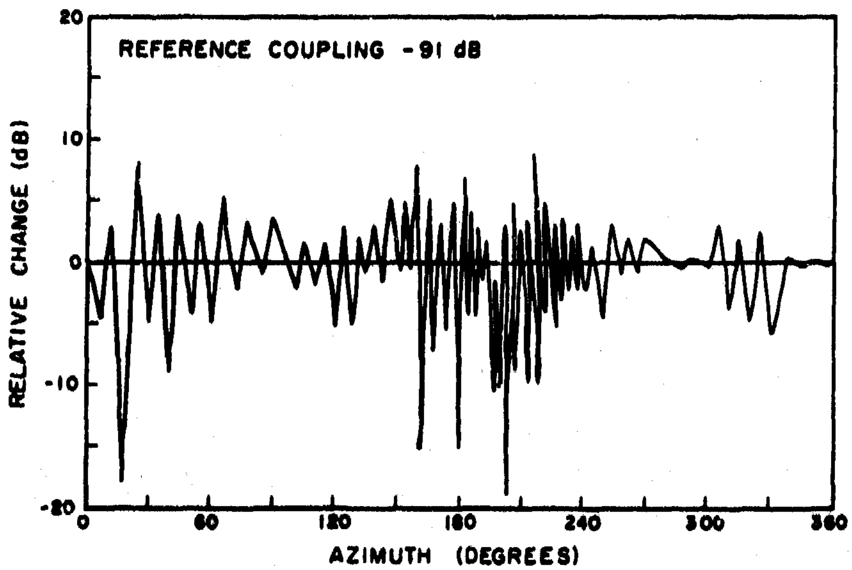

Figure 9. System Response to a Maxivan (0.5 m from leaky cable)

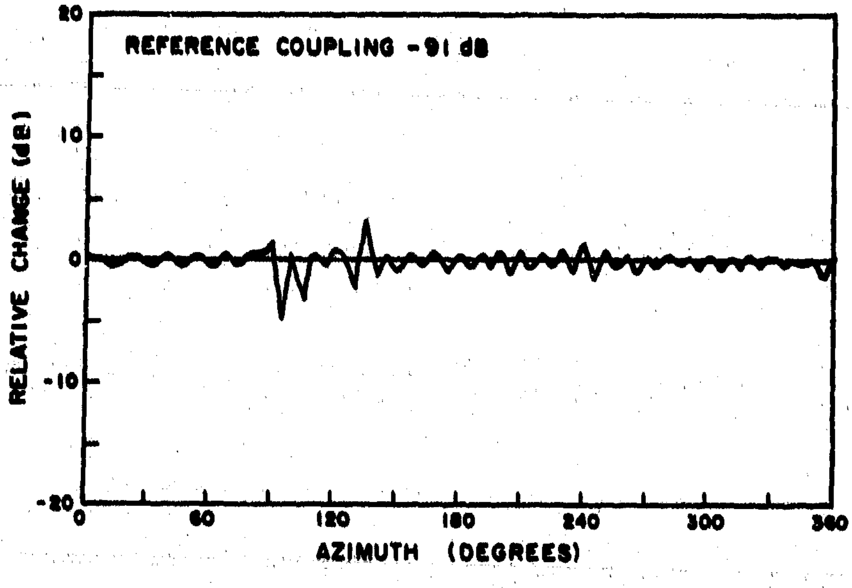

Figure 10. System Response to a Maxivan (2.0 m from leaky cable)

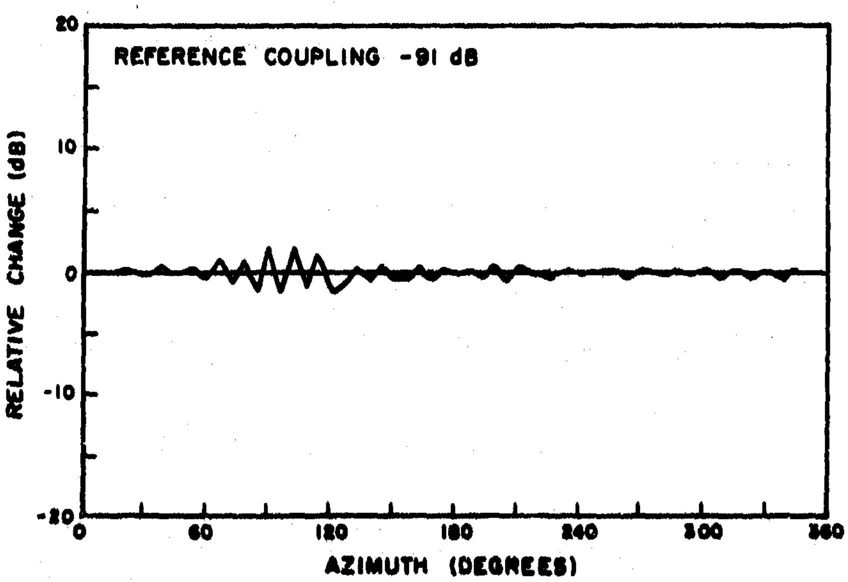

Figure 11. System Response to a Maxivan (3.5 m from leaky cable)

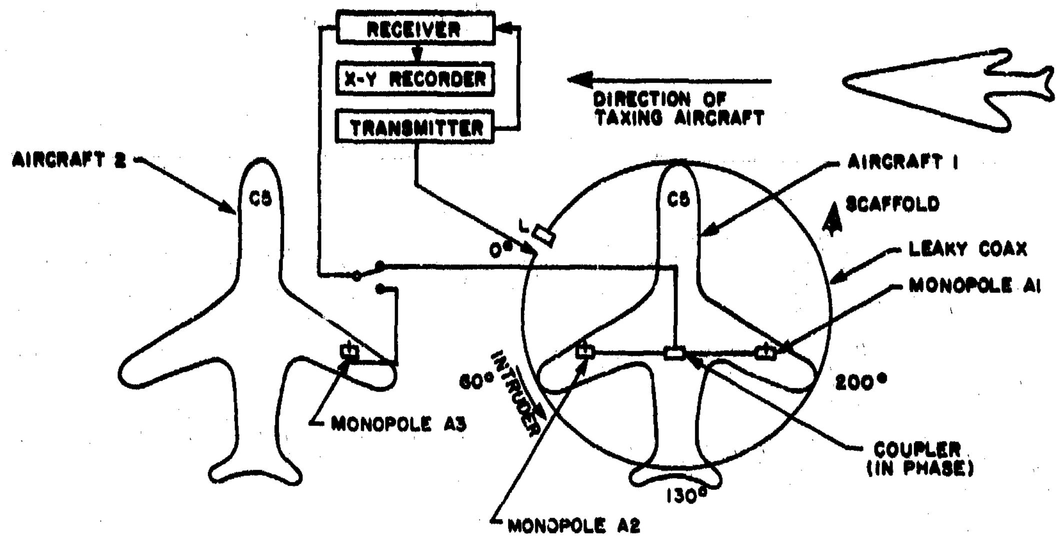

Figure 12. Field Site Layout (mutual interference tests)

2.4 Mutual Interference of Adjacent System

In practice, several systems would normally be deployed around adjacent aircraft and it is necessary, therefore, to investigate the mutual coupling between systems. Though operating frequencies of adjacent systems can be different, for these tests a single frequency was used.

The measurement setup is shown in Figure 12, but only one monopole A3 under aircraft 2 was used as receiving element while the length of leaky coax encircled aircraft 1. The signal received by monopole A3 as a monopole intruder walked around the leaky coax cable surrounding aircraft 1 was measured to determine the degree of coupling between the two systems. The signal power received by A3 as the intruder made two "circumferential walks" is represented in Figures 13 and 14. Figure 13 shows a region of very strong response starting at 0° and continuing through 90°, and then a rapid drop-off in amplitude as a function of azimuth. Within this sector a change in frequency of the fast response from 4 cycles per 30° to 10 cycles per 30° sector is also evident.

The large intruder response within this sector is due to two factors. First, the intruder is closest to the receiving antenna A3 and second, this segment of the cable is the most sensitive since it is near the feed. Elsewhere, the disturbance is very weak because the cable sensitivity is decreasing, the distance from the intruder to the antenna is increasing, and the severity of shadowing by the aircraft is increasing. Next, the feed and the load ends of the

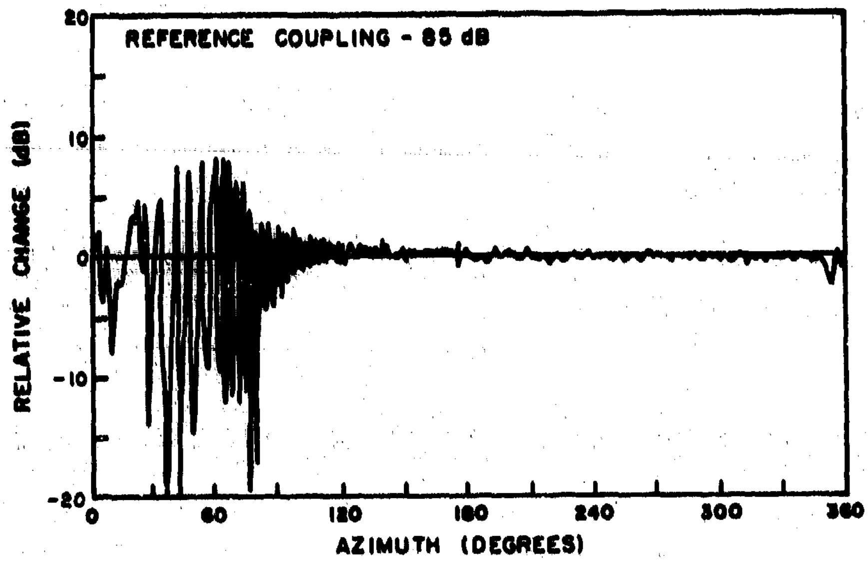

Figure 13. Monopole Response to Adjacent System Circumferential Walk (cable feed near)

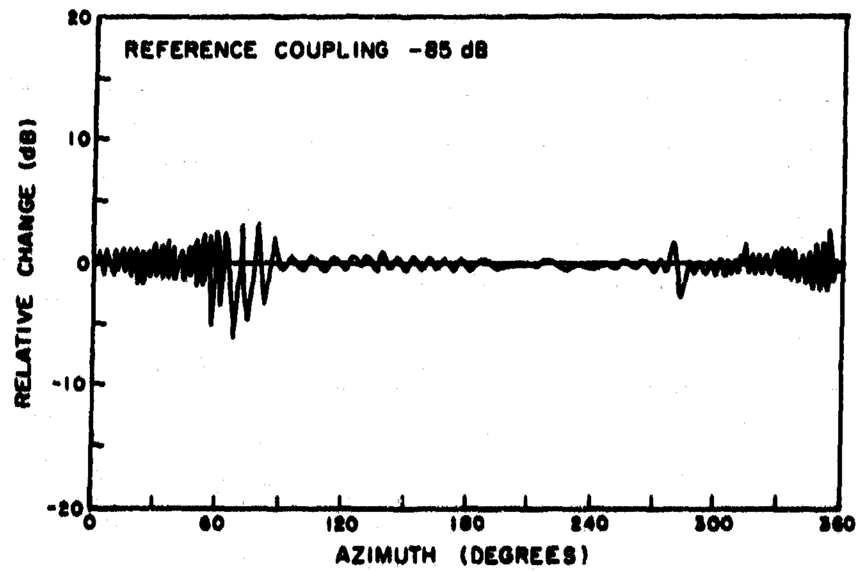

Figure 14. Monopole Response to Adjacent System Circumferential Walk (cable feed opposite)

leaky cable were interchanged. The results evident in Figure 14, show a similar but reduced response pattern since now the leaky coaxial cable segment near the point of closest approach is near the weak end of the sensor.

3. CONCLUSIONS

The results of these tests showed several characteristics of the SWIRPS.

a. A single monopole used as the receiving element to protect a C-5A fails to provide adequate circumferential detection coverage. Two coupled antennas, however, one on each side of the fuselage, will give complete coverage. Further, an increased intruder response at all angles was observed when the antennas were raised above the ground.

b. As anticipated, because of the confined detection zone, peripheral activity by maintenance vehicles does not cause false alarms. For example, a maintenance maxivan caused a false alarm only when it had traveled to within less than 3 m from the cable. Additionally, aircraft (about 15 m from the cable) taxiing on the runway ramp caused negligible effects on the received signal.

c. Two adjacent active systems will interact, as expected, and any system design, therefore, would incorporate provisions to prevent mutual interference. For example, use of different subcarrier frequencies or coherent detection techniques in each SWIRPS would eliminate any existing mutual interference between systems.

d. Finally, it should be emphasized that these results are valid only for C-5A aircraft. Other aircraft or resources would probably change the specific response, but not the overall performance of the SWIRPS.

References

1. Karas, N.V., Poirier, J.L., Antonucci, J.A., and Szczytko, M., Sgt, USAF (1978) A VHF Intrusion Detection Technique for Isolated Resources, RADC-TR-78-177, AD A060791.

2. Poirier, J.L., Karas, N.V., Antonucci, J.A., and Szczytko, M., Sgt, USAF (1977) VHF Intrusions Detection: A Technique for Parked Aircraft, RADC-TR-77-384, AD A051144.

3. Rochefort, J.S., Sukys, R., and Poirier, N.C. (1978) An Area Intrusion Detection and Alarm System, RADC-TR-78-258, AD A063259.

4. Karas, N.V., Antonucci, J.A., and Szczytko, M., Sgt, USAF (1978) A VHF Intruder Detection System: Tests on a C-5A Aircraft, RADC-TR-78-230, AD A066300.

5. Poirier, J.L., and Kushner, M. (1979) Analysis of the Response of an RF Intruder Protection System, RADC-TR-79-17, AD A072816.

6. Poirier, J.L. (1979) Effect of Multiple Receiving Antennas on the Response of an RF Intrusion Sensor, RADC-TR-79-42, AD A072819.

7. Poirier, J.L. (1980) Estimation of the Zone of Detection of the Single Wire Individual Resource Protection Sensor, RADC-TR-80-258, AD A094137.

MISSION
of
Rome Air Development Center

RADC plans and executes research, development, test and selected acquisition programs in support of Command, Control Communications and Intelligence (C^3I) activities. Technical and engineering support within areas of technical competence is provided to ESD Program Offices (POs) and other ESD elements. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.

Printed by
United States Air Force
Hanscom AFB, Mass. 01731